TANTA UNIVERSITY

Electrical Power and Machines Department

Faculty of Engineering

Final EXAM 2014/2015- Second Term

Course	Electrical Circuits (2) (EPM1203)	Time Allowed	3 hours
Students	1st Year (Electrical)	Total Marks	85
Date	Wed,June10, 2015	Number of pages	3

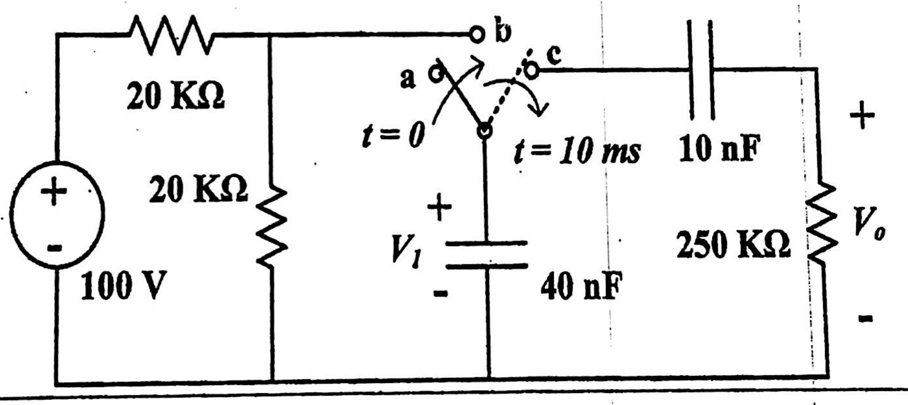
<u>تعليمات عامة</u>	١. تجنب قدر المستطاع استخدام القلم الرصاص فيما سوى الرسومات.
٢. اكتب رقم السؤال بوضوح.	٣. تجنب تماما استخدام اللونين الأحمر والأخضر في إجاباتك.
٤. لا تستخدم سائل التصحيح corrector	٥. يراعى قدر المستطاع أن تبدأ إجابة كل سؤال في صفحة جديدة.
٦. لا يشترط الإجابة بترتيب الأسئلة في ورقة الامتحان.	٧. أجب بوضوح سواء باللغة الإنجليزية أو العربية.

Answer ALL the following FIVE questions and problems:

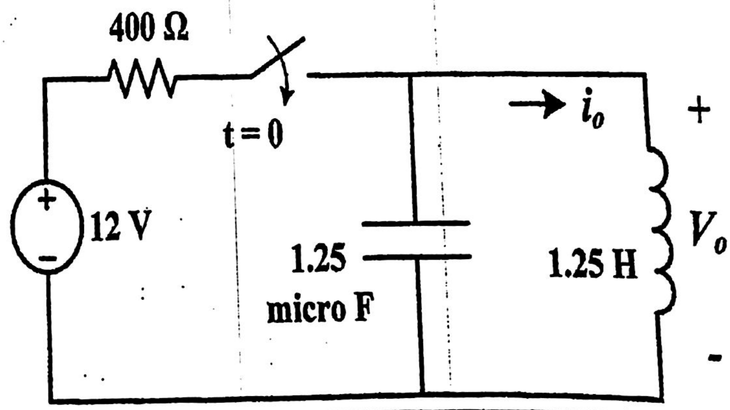
- ***Clarify your answer with the suitable sketches of complete data as you can.***
- ***Assume any missed data reasonably.***

The first question (12 marks)

The switch in the circuit shown in figure has been in position "a" for a long time while initial charge on both capacitors was zero. At $t = 0$, the switch has been moved to position "b". After a time of 10 ms, it has been moved to position "c". **<u>Find</u>** and **<u>plot</u>** time expressions for v_o and v_1



The second question (16 marks)

1.	With suitable relations and illustrations **<u>compare</u>** between **the effect of resistance R on the step-response of <u>parallel</u> and <u>series</u> RLC circuits.(4 marks)**
2.	In the circuit in figure, there was no stored energy when the switch is closed at time t=0. **Find** time expressions of both v_o and i_o for $t \geq 0$ **(12 marks)** 

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The third question (20 marks)

a) The magnitude of the phase voltage of an **ideal balanced** three-phase Y-connected (***four-wire***) source is **240 V**. The source is connected to a balanced Y- connected load by a distribution line that has impedance of **0.4+j1.5 Ω/phase**. The per-phase impedance of the load is **21.6+j4.5 Ω**. The phase sequence of the source is **acb**. Use the a-phase voltage of the source as the reference.**(9 Marks)**

(i) **Construct** a single-phase equivalent circuit. 1 $Z = 22.8 \angle 15.26$

(ii) **Specify** the magnitude and phase angle of the following: $I_{aA} = 10.53 \angle -15.26$

1. The **four** line-currents 2
2. The **three** line-voltages at the terminals of the source 2 $V_{bs} = 415 \angle -30$
3. The **three** line-voltages at the terminals of the load 2 $V_{AB} = 402.41 \angle 33.49$

(iii) **Calculate** the total instantaneous power delivered by the generator. 2 $P = 7314.28$

b) Two balanced Δ-connected loads, with impedances **20∠-60 Ω** and **18∠45 Ω**, respectively, are connected to a three-phase system for which a line voltage is **V_{BC}= 212∠0 V**. **(11 Marks)**

(i) **Obtain** the per-phase average, reactive and complex power of each load. 4 P= Q= S=

(ii) **Specify** the magnitude and phase-angle of the three line currents I_{aA}, I_{bB} and I_{cC}. 4+1 $I_{aA} = 23.66 \angle$

(iii) **Compute** the total delivered power, and **compare** with the sum of the phases power 2 P 28668.3 W

The fourth question (18 marks)

a) **Two magnetically-coupled coils have self-inductances L_1 = 50 mH and L_2 = 200 mH, and a coefficient of coupling k = 0.5.If coil 2 has 1000 turns, and i_1 = 5.0 sin 400t (A), (5 Marks)**

(i) **Find** the induced voltage at coil 2 and the flux of coil 1, Φ_1. 3 100 Cos400t volt, 0.5 Sin400t mWb

(ii) **Determine** the number of turns of the first coil. (Assume that the physical structure of these coupled coils is such that the P_{11} and P_{22} are equal). 1 500 turns

(iii) **What is the value of P_1 and P_2?** 1 0.2×10^{6}

b) **The circuit shown has two magnetically-coupled coils with a maximum coefficient of coupling.**

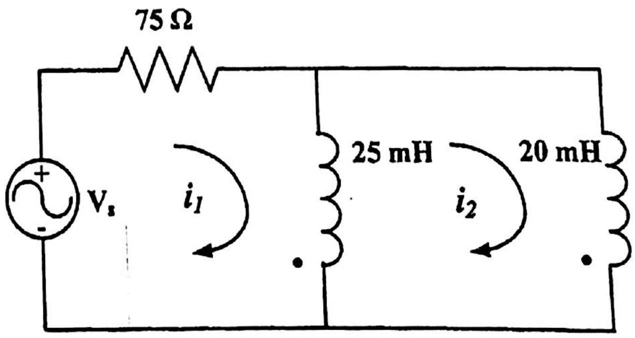
(10 Marks)

(i) **Determine** the mutual inductance between the two magnetically-coupled coils. 1 22.36 mH

(ii) **Write** a set of mesh-current equations that describe the circuit in terms of i_1 *and* i_2 (in both time and frequency domain). 4

(iii) **Simplify** the parallel branches, containing 25 mH and 20 mH coils, to a single equivalent coil. 2

(iv) **Starting with** the stored energy calculation form, **derive** an expression of the maximum mutual inductance between two magnetically-coupled coils. 3



c) **Show how the polarity marking on the two magnetically-coupled coils can be determined experimentally.** **(3 Marks)**

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The fifth question (20 marks)

1. **Sketch** with sufficient details the input-output characteristics of operational amplifier.

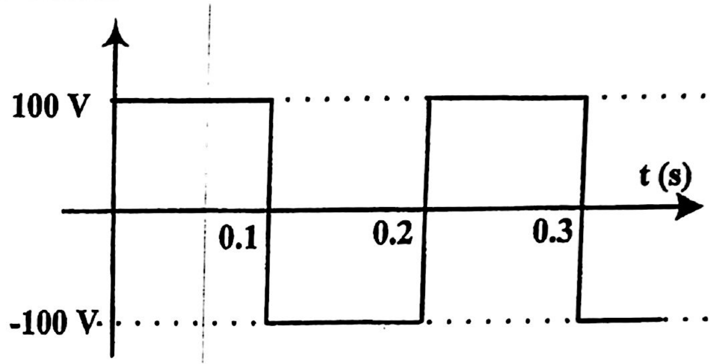
(3 marks)

2. With the aid of **a circuit diagram** and **suitable relations, explain** how an operational amplifier can be used to get difference between two signals. Clarify how to achieve *unity scaling factors*.

(4 marks)

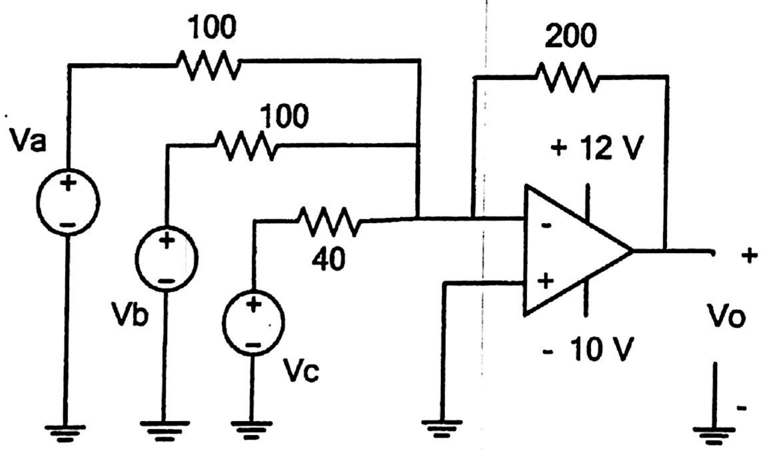
3. The shown voltage waveform represents the input to an integrating amplifier. The positive power supply terminal is connected to +15 V, while the negative terminal is connected to -10 V. Sketch the output voltage waveform.

(4 marks)



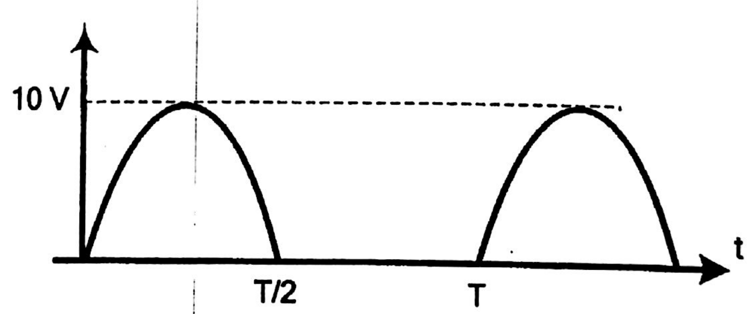
4. The operational amplifier shown in figure is ideal. The values of the shown resistances are in k Ω. **Specify** the range of **Vc** required to avoid amplifier saturation when

Va =3 V and **Vb = 2 V** **.(4 marks)**



5. Find the Fourier series spectrum of the half-wave rectified sinusoidal voltage shown in figure

(5 marks)



Good Luck and best wishes

Prof. Essam Eddin M. Rashad, Dr. Said M. Allam and exam committee

The Second Question

① Parallel 2 لكل

$\frac{d^2v}{dt^2} + \frac{1}{RC}\frac{dv}{dt} + \frac{1}{LC} v = 0$ (with $\frac{1}{RC} = 2\alpha$, $\frac{1}{LC} = \omega_0^2$)

تعريف α لكل

$\boxed{\alpha = \frac{1}{2RC}}$

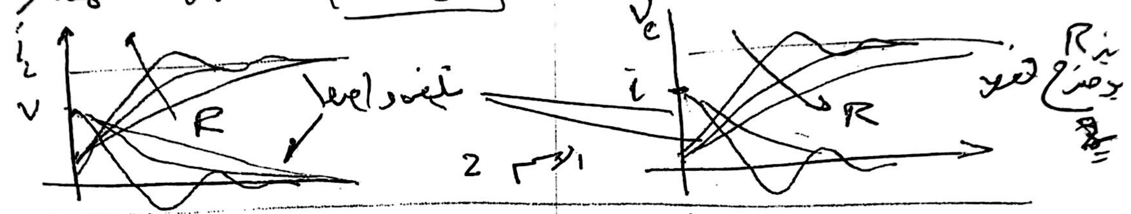
series

$\frac{d^2i}{dt^2} + \frac{R}{L}\frac{di}{dt} + \frac{1}{LC} i = 0$

$\alpha \quad \omega_0$

$\boxed{\alpha = \frac{R}{2L}}$

④ $\alpha > \omega_0$ over



② $\alpha = \frac{1}{2RC} = 1000$ | over damped
$\omega_0 = \frac{1}{\sqrt{LC}} = 800$

30 mA, 400, 1.25, 1.25 H

4 $S_1 = -400$ | $S_2 = -1600$

$V_0 = V_f + A_1 e^{-400t} + A_2 e^{-1600t}$

(12) $V_f = 0 \qquad V_0(0) = 0 \qquad i(0) = 30\text{ mA}$

$A_1 + A_2 = 0 \qquad \frac{i(0)}{C} = \frac{dv}{dt}(0) = 24000$

$-400A_1 - 1600A_2 = 24000$

$A_1 = 20$ | $A_2 = -20$

5 $\boxed{V_0 = 20e^{-400t} - 20e^{-1600t}}$

$i_0 = I_f + A_1' e^{-400t} + A_2' e^{-1600t}$

$I_f = 30\text{ mA}$ | $i_L(0) = 0$ | $\frac{di}{dt}(0)$

$0 = 30 + A_1' + A_2'$ | $-400A_1' - 1600A_2' = 0$

$A_1' = -40\text{ mA} \qquad A_2' = 10\text{ mA}$

5 $\boxed{i_0' = 30 - 40e^{-400t} + 10e^{-1600t}}$

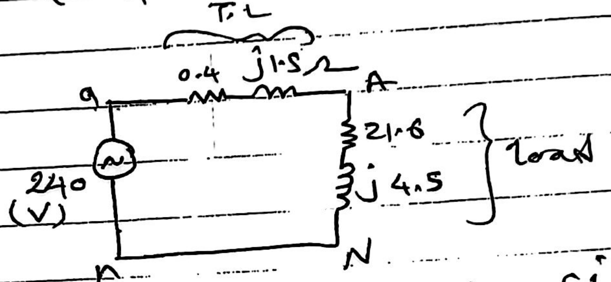
$L\frac{di}{dt} \longrightarrow V_0$ check or another solve

نموذج اجابة امتحان دوائر كهربية (٢)

فصل دراسي ثاني ٢٠١٤-٢٠١٥

الجزء الثاني

Q.3 : (a)



1-ph Eq. circuit (i)

(i)

$$I_{aA} = \frac{V_{an}}{Z_{T.L}+Z_L} = \frac{240\angle 0}{22+j6} = \frac{240\angle 0}{22.8\angle 15.26} = 10.53\angle -15.26 \ A$$

(1)

$$I_{bB} = 10.53\angle 104.74 \ A$$

$$I_{cC} = 10.53\angle -135.26 \ A$$

&

$$V_{ab} = \sqrt{3}\angle 30 \ V_{an} = 415\angle 30 \ V$$

$$V_{bc} = 415\angle -90 \ V$$

$$V_{ca} = 415\angle 150 \ V$$

(2) the line voltage at the source terminals

$$I_{nN} = \text{Zero}$$

$$V_{AN} = I_{aA} Z_L = 10.53\angle -15.26 * 22.064\angle 11.77 = 232.33\angle -3.49 \ \text{volt}$$

(3)

$$V_{AB} = \sqrt{3}\angle 30 \ V_{AN} = 402.41\angle 33.49 \ \text{volt}$$

$$V_{BC} = 402.41\angle -86.51 \ \text{volt}$$

$$V_{CA} = 402.41\angle 153.49 \ \text{volt}$$

line voltage at the Load terminals

(iii) $P = 3 V_{ph} I_{ph} \cos\phi$

$$= 3 * 240 * 10.53 \cos(15.26)$$

$$= 7314.28 \ \text{watt}$$

CIR 2 14/1/5

The Second Question

(1) Parallel

$$\frac{d^2v}{dt^2} + \underbrace{\frac{1}{RC}}_{2\alpha}\frac{dv}{dt} + \underbrace{\frac{1}{LC}}_{\omega_0^2} v = 0$$

$$\boxed{\alpha = \frac{1}{2RC}}$$

series

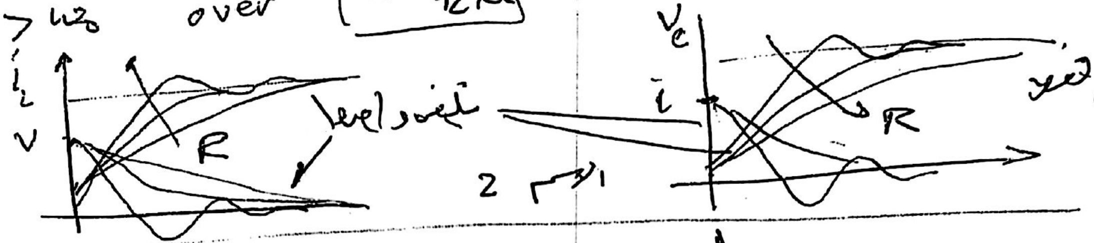
$$\frac{d^2i}{dt^2} + \frac{R}{L}\frac{di}{dt} + \frac{1}{LC} i = 0$$

$\alpha \quad \omega_0$

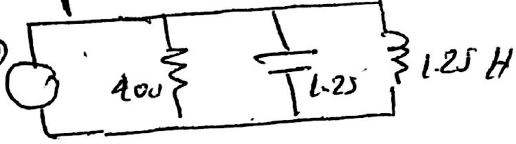
$$\boxed{\alpha = \frac{R}{2L}}$$

4

$\alpha > \omega_0$ over



(2) $\alpha = \frac{1}{2RC} = 1000$, $\omega_0 = \frac{1}{\sqrt{LC}} = 800$ } over damped



4

$S_1 = -400 \quad | \quad S_2 = -1600$

$$V_o = V_f + A_1 e^{-400t} + A_2 e^{-1600t}$$

(12)

$V_f = 0 \qquad V_o(0) = 0 \qquad i(0) = 30\,mA$

$A_1 + A_2 = 0 \qquad \frac{i(0)}{C} = \frac{dv}{dt}(0) = 24000$

$-400A_1 - 1600A_2 = 24000$

$A_1 = 20 \quad | \quad A_2 = -20$

5

$$\boxed{V_o = 20e^{-400t} - 20e^{-1600t}}$$

$$i_o = I_f + A_1' e^{-400t} + A_2' e^{-1600t}$$

$I_f = 30\,mA \quad | \quad i_o(0) = 0 \qquad \frac{di}{dt}(0)$

$0 = 30 + A_1' + A_2' \qquad -400A_1' - 1600A_2' = 0$

$A_1' = -40\,mA \qquad A_2' = 10\,mA$

5

$$\boxed{i_o' = 30 - 40e^{-400t} + 10e^{-1600t}}$$

$L\frac{di}{dt} \longrightarrow V_o$ check or another solve

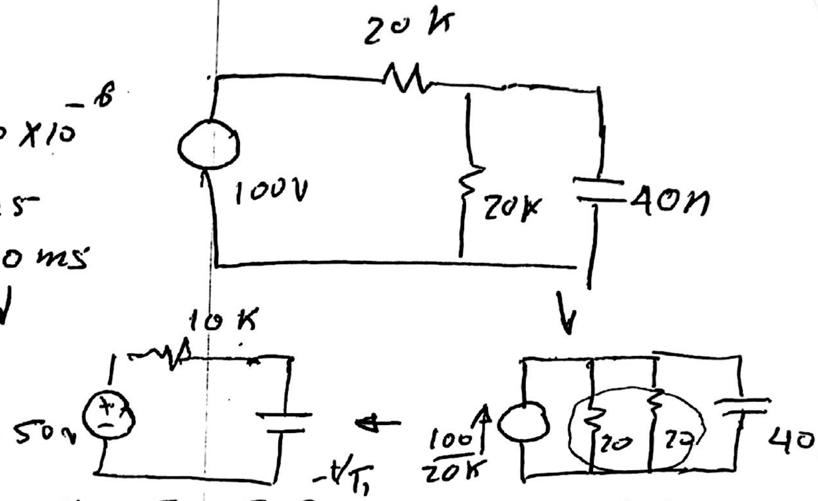
2014/2015

The First Question

- $t \quad 0 \rightarrow 10\ ms$

$T_1 = 10K * 40n = 400 \times 10^{-6}$

$5T_1 = 2000 \times 10^{-6} = 2\ ms < 10\ ms$

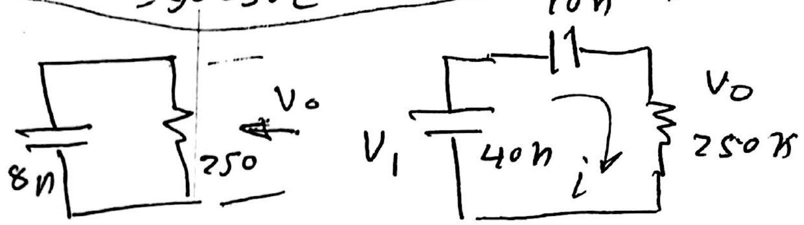


2 hense cirut approched steady state

1 $V_{C10} = 50\ V$

$V_1 = 50 - 50e^{-t/T_1} = 50 - 50e^{-2500t}$

- $t > 10\ ms$



$T_2 = 250K * 8nF = 2000 \times 10^{-6}\ s = 2\ ms$

1

$$v_0 = V_{C10}\, e^{-(t-0.01)/T_2} = 50\, e^{-500(t-0.01)}\ V$$

3 $\boxed{V_o = 50\, e^{-500(t-0.01)}}$ $t \geq 0$

$$v_1 = \frac{1}{40n} \int i\, dt + 50$$

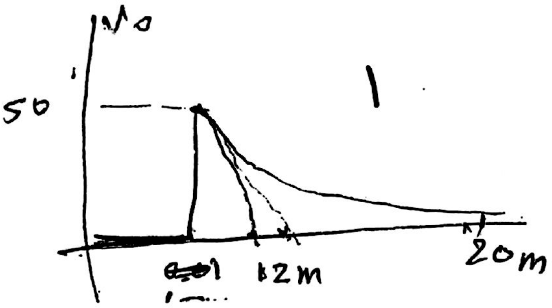
$$i = \frac{V_o}{250K} = \frac{200}{0.2} e^{-500(t-0.01)}\ \mu A \quad mA$$

3

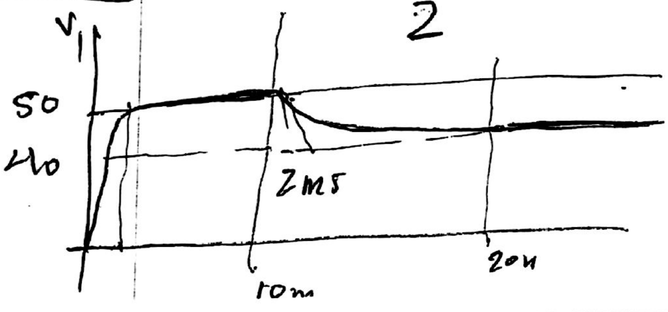
$$v_1 = \frac{1}{40n} * 200 \times 10^{-6} \int_0^t e^{-500(t-0.01)} + 50$$

$$= \frac{5 \times 10^3}{500}\left[e^{-500(t-0.01)} \Big|_0^t + 50 \right] = -10 e^{-500(t-0.01)} \Big|_0^t + 50$$

3 $\boxed{V_1 = 10 e^{-500(t-0.01)} + 40}$



1



2

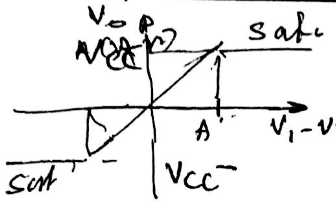
CIR2 14/15

The Fifth Question

20

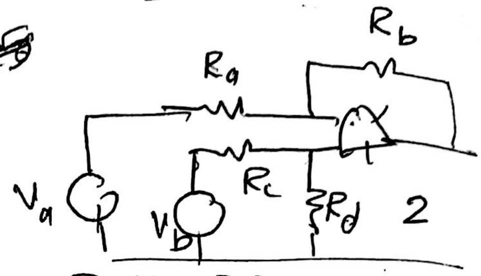
1

3



2

4



2

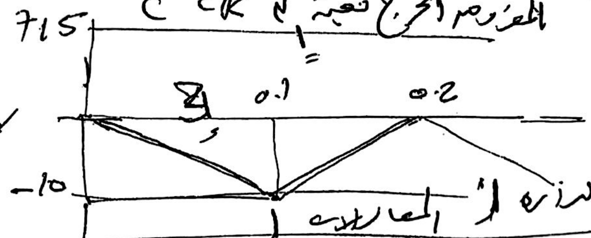
$$V_o = \frac{R_d(R_a+R_b)}{R_a(R_c+R_d)} V_b - \frac{R_b}{R_a} V_a \quad 2$$

For equal scaling for unity

$$\frac{R_b}{R_a} = \frac{R_d}{R_c} = 1$$

3

4



4 $\quad V_o = -\left[\frac{200}{100} V_a + \frac{200}{100} V_b + \frac{200}{40} V_c\right] \quad V_a = 3, \; V_b = 2$

1

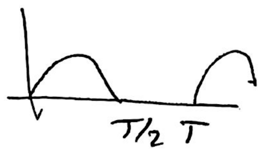
4 $\quad V_o = -10 - 5 V_c$

For $V_o = +12 \longrightarrow V_c = -4.4\,V$ 1

$V_o = -10 \longrightarrow V_c \quad 0$ 1

$$\boxed{-4.4 < V_c < 0} \quad 1$$

5 $\quad a_o = \frac{1}{T}\int_0^{T/2} V_m \sin \frac{2\pi}{T} t \, dt = \frac{V_m}{\pi}$



$$= \frac{10}{\pi} = \boxed{3.183} \quad 1$$

5

$$a_K = \frac{2}{T}\int_0^{T/2} V_m \sin \frac{2\pi}{T} t \cos K\omega_o t \, dt$$

$$= \frac{V_m}{\pi}\left[\frac{1+\cos K\pi}{1-K^2}\right] \quad 2 \quad \boxed{\begin{matrix} 0 & \text{odd } K \\ \frac{2V_m}{\pi(1-K^2)} & \text{even } K \end{matrix}}$$

$$b_K = \frac{2}{T}\int_0^{T/2} V_m \sin \frac{2\pi}{T} t \, \sin K\omega_o t \, dt$$

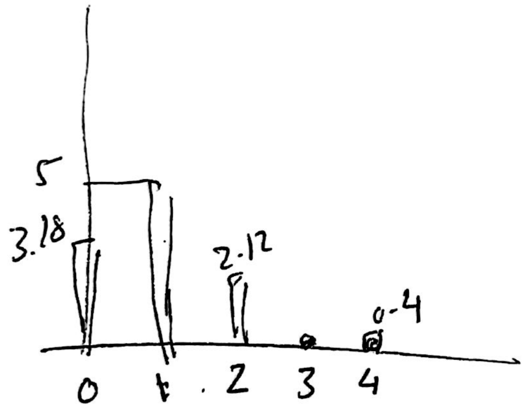
2

$$= 0 \quad K = 2, 3, 4 \ldots$$

$$b_1 = \boxed{\frac{V_m}{2}} \quad 1$$

1

n	0	1	2	3	4	5
C_n	$\frac{10}{\pi}$	$\frac{10}{2}$	$\frac{20}{3\pi}$	0	$\frac{20}{15\pi}$	0
	3.18	5	2.12	0	0.424	0



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(b) $V_{BC} = 212\angle 0$, $Z_1 = 20\angle -60$

$Z_2 = 18\angle 45$

$I_{BC_1} = \dfrac{212\angle 0}{20\angle -60} = 10.6\angle 60$ A

$I_{BC_2} = \dfrac{212\angle 0}{18\angle 45} = 11.78\angle -45$ A

(i) for Load (1) $P_1 = 212 * 10.6 \cos 60 = 1123.6$ W

$Q_1 = 212 * 10.6 \sin 60 = 1946.13$ VAR

$S_1 = 212 * 10.6 = 2247.2$ VA

for Load (2) $P_2 = 212 * 11.78 \cos 45 = 1765.9$ W

$Q_2 = 212 * 11.78 \sin 45 = 1765.9$ VAR

$S_2 = 212 * 11.78 = 2497.36$ VA

(ii) $I_{bB} = \sqrt{3}\left[10.6\angle 60-30 + 11.78\angle -45-30\right]$

$= \sqrt{3}\left[10.6\angle 30 + 11.78\angle -75\right]$

$= \sqrt{3}\left[9.18 + j5.3 + 3.05 - j11.39\right]$

$= \sqrt{3} * \left[12.23 - j6.09\right] = \sqrt{3} * 13.66\angle -26.47$

$I_{aA} = I_{bB}\angle 120 = 23.66\angle 93.53^\circ$ A

$I_{cC} = 23.66\angle 213.53$ A

($I_{BC} = 13.66\angle 3.53$ A)

(iii) $P_{total} = \sqrt{3} V_L I_L \cos\phi$

$= \sqrt{3} * 212 * 23.66 * \cos(3.53)$

$= 8671.34$ watt

$P_{1,2} = 3(P_1 + P_2) = 3(1123.6 + 1765.9)$

$= 8668.5$ watt

Q-4 $\boxed{a}$

(i) $e_2 = M \frac{di_1}{dt}$ $\longrightarrow M = K\sqrt{L_1 L_2}$

$= 50\ mH$

$= 0.05 \frac{d}{dt}(5 \sin 400t)$

$= 400 * 5 * 0.05 \cos 400t$

$= 100 \cos 400t$ volt

$\lambda_{21} = M i_1 = 0.05 * 5 \sin 400t$

$= 0.25 \sin 400t$

$\phi_{21} = \frac{\lambda_{21}}{N_2} = 0.25 \sin 400t$ m wb

$\phi_1 = \frac{\phi_{21}}{K} = 0.5 \sin 400t$ m wb

(iii) $P_1 = P_2 = \frac{L_2}{(N_2)^2} = \frac{200 * 10^{-3}}{(1000)^2} = 0.2 * 10^{-6}$

(ii) $L_1 = (N_1)^2 P_1 \longrightarrow N_1 = \sqrt{\frac{L_1}{P_1}} = 500$ turns

$\boxed{b}$ $M_{max} = \sqrt{20 * 25} = 22.36$ mH (i)

(ii) $v_s = 75 i_1 + 25 * 10^{-3} \frac{d}{dt}(i_1 - i_2) + 22.36 * 10^{-3} \frac{di_2}{dt}$

$0 = 20 * 10^{-3} \frac{di_2}{dt} + 25 * 10^{-3} \frac{d}{dt}(i_2 - i_1)$

$- 22.36 * 10^{-3} \frac{d}{dt}(i_2 - i_1) - 22.36 * 10^{-3} \frac{d}{dt} i_2$

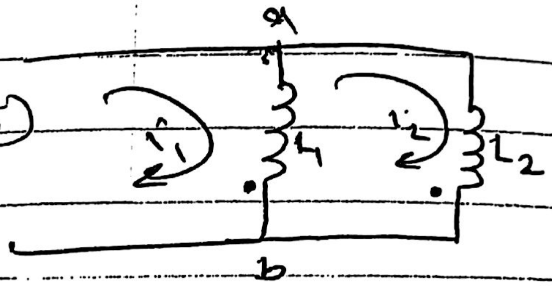
in frequency domain $\longrightarrow V_s = 75 i_1 + j\omega * 25 * 10^{-3} (i_1 - i_2)$

$+ j\omega * 22.36 * 10^{-3} i_2$

& $0 = j\omega * 20 * 10^{-3} i_2 + j\omega * 25 * 10^{-3} (i_2 - i_1)$

$- j\omega * 22.36 * 10^{-3} (i_2 - i_1) - j\omega * 22.36 * 10^{-3} i_2$

iii)



$$v_{ab} = L_1 \frac{d(i_1-i_2)}{dt} + M\frac{di_2}{dt} \longrightarrow (I)$$

$$0 = L_2 \frac{di_2}{dt} - M\frac{d(i_2-i_1)}{dt}$$
$$+ L_1\frac{d(i_2-i_1)}{dt} - M\frac{di_2}{dt}$$

$$0 = (L_2+L_1-2M)\frac{di_2}{dt} + (-L_1+M)\frac{di_1}{dt}$$

$$\frac{di_2}{dt} = \frac{L_1-M}{L_1+L_2-2M}\frac{di_1}{dt} \longrightarrow II$$

from (II) in (I)

$$v_{ab} = L_1 \frac{di_1}{dt} + (-L_1+M)\frac{L_1-M}{L_1+L_2-2M}\frac{di_1}{dt}$$

$$= \frac{\cancel{L_1^2}+L_1L_2-\cancel{2ML_1}-\cancel{L_1^2}+\cancel{ML_1}+\cancel{ML_1}-M^2}{L_1+L_2-2M}\frac{di_1}{dt}$$

$$= \frac{L_1L_2-M^2}{L_1+L_2-2M}\frac{di_1}{dt}$$

$$\therefore L_{eq} = \frac{L_1L_2-M^2}{L_1+L_2-2M} = \frac{20*25-(22.36)^2}{20+25-44.72}$$

$$= \text{zero}$$

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(iv)

$$W_{stored} = \tfrac{1}{2} L_1 i_1^2 + \tfrac{1}{2} L_2 i_2^2 \pm M i_1 i_2$$

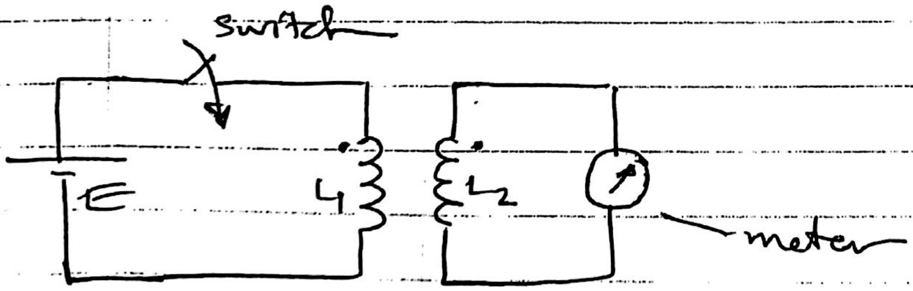
$$W > 0 \longrightarrow \tfrac{1}{2} L_1 i_1^2 + \tfrac{1}{2} L_2 i_2^2 - M i_1 i_2 > 0$$

$$\underbrace{\left(\sqrt{\tfrac{L_1}{2}}\, i_1 - \sqrt{\tfrac{L_2}{2}}\, i_2\right)^2}_{\geq 0} + \left(\sqrt{L_1 L_2}\, i_1 i_2 - M i_1 i_2\right) > 0$$

$$\therefore \sqrt{L_1 L_2}\, i_1 i_2 - M i_1 i_2 > 0$$

$$M < \sqrt{L_1 L_2} \longrightarrow \underbrace{M_{max} = \sqrt{L_1 L_2}}$$

(c)



for (+ve) Reading of meter → the dot location is right

for (−ve) Reading of meter → one dot should be changed

(iv)

$$W_{stored} = \frac{1}{2}L_1 i_1^2 + \frac{1}{2}L_2 i_2^2 \pm M i_1 i_2$$

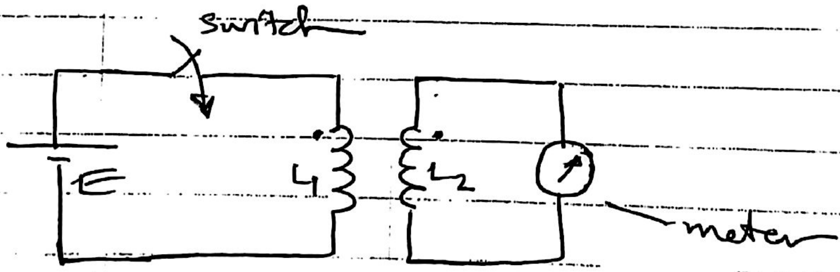
$$W > 0 \rightarrow \frac{1}{2}L_1 i_1^2 + \frac{1}{2}L_2 i_2^2 - M i_1 i_2 > 0$$

$$\underbrace{\left(\sqrt{\frac{L_1}{2}}\, i_1 - \sqrt{\frac{L_2}{2}}\, i_2\right)^2}_{\geq 0} + \left(\sqrt{L_1 L_2}\, i_1 i_2 - M i_1 i_2\right) > 0$$

$$\therefore \sqrt{L_1 L_2}\, i_1 i_2 - M i_1 i_2 > 0$$

$$M < \sqrt{L_1 L_2} \rightarrow \underline{M_{max} \sqrt{L_1 L_2}}$$

(c)



for (+ve) Reading of meter ∴ the dot location is right

for (−ve) Reading of meter ∴ one dot should be changed